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CITY OF BOSTON
BOSTON, MASSACHUSETTS

REPORT
OF
INVESTIGATION OF COLLAPSE
AT
HOTEL VENDOME

2944-1

AUGUST, 1972

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MAIN
CHAS. T. MAIN, INC.
Engineers

SOUTHEAST TOWER, PRUDENTIAL CENTER, BOSTON, MASSACHUSETTS 02199 • TELEPHONE 617-262-3200

August 18, 1972

2944-1

SUBJECT: Investigation of Collapse
at Hotel Vendome

Mr. R. R. Thuma, Jr.
Building Commissioner
City of Boston
City Hall
Boston, Massachusetts 02201

Dear Mr. Thuma:

In accordance with your request of June 20, 1972, we have made an investigation and analysis of the partial collapse of the Hotel Vendome during a fire on June 17, 1972.

The results of our investigation are included in this report; if you so desire, we will be pleased to meet with you to discuss the contents.

It is our opinion that the collapse of the structure was caused by a failure of the bearing wall under the cast-iron column at the first floor. The failure of the bearing wall was in all probability due to a combination of the following factors:

1. The stresses under the cast-iron column were excessively high as a result of removing the bearing wall between the first and second floors around 1890 and replacing the wall with a beam and column support system. The masonry bearing walls are approximately 100 years old and the mortar exhibits very low strength characteristics, both in bond and bearing. It is our opinion that this alteration was the major factor contributing to the building collapse.



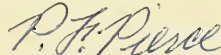
2. The addition of a heating and ventilating duct opening in the bearing wall in the area under the column, during the 1972 alterations, caused additional stress concentrations.

3. The fire in this portion of the building which destroyed the roof was responsible for the collapse only to the extent that the large amount of water pumped into the building during the fire provided the additional load needed to trigger the collapse. If the residual stresses in the building, however, had been within normal design limits, this water load should not have caused collapse of the structure.

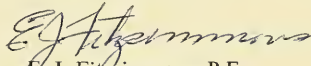
We wish to thank the City of Boston Building Department, the Boston Fire Department and the many individual citizens who assisted us in obtaining the information necessary for preparation of this report.

Very truly yours,

CHAS. T. MAIN, INC.



By: P. F. Pierce, P.E.



By: E. J. Fitzsimmons, P.E.

PFP/EJF/cm



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Supplement - filed at end of volume



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I. SCOPE OF WORK

This report has been prepared for the City of Boston in accordance with the request of Mr. R. R. Thuma, Jr., Building Commissioner, on June 20, 1972.

The scope of this report includes an investigation of the partial collapse of the Hotel Vendome, 160 Commonwealth Avenue, Boston, Massachusetts, during a fire on June 17, 1972 in which nine firemen were killed. The purpose is to establish, if possible, the cause of the collapse of the structure.

Our investigation has been restricted to the collapsed portion of the structure and the scope of our work did not include the evaluation of the integrity of the remainder of the structure.

The basic approach to our investigation included the following:

1. Review of original drawings.
2. Review of alteration drawings for the renovations which were in progress when the fire started.
3. Examination of debris in an attempt to establish the building structural system immediately prior to collapse and to determine the dead load of the structure.
4. Interviews with witnesses who observed the collapse and with persons involved in the renovation design and construction.
5. Laboratory testing of several of the structural components.
6. Structural analysis of the structure.

II. HISTORY OF HOTEL VENDOME

The collapsed section represented the South half of the original construction. Architect W. G. Preston's drawings indicate that this construction took place in the year 1870 to 1875. Plans dated 1875 first identify the structure as the Hotel Vendome.

This original construction consisted of five floors and basement fronting on Dartmouth Street with a separate entrance on Commonwealth Avenue.

A low section incorporating a passage and dining hall connected this structure with a group of five "houses" further west.

At a later date, circa 1880, this passage area was filled in with a full height structure presenting substantially the appearance shown prior to the fire.

In 1911, a solarium area was added over the roof at the Northeast corner.

The Dartmouth Street building was of brick bearing wall construction resting on a pile foundation. The exterior walls were faced with stone on the Dartmouth Street and Commonwealth Avenue sides. The floors were of wood construction with wood joists resting in pockets in the bearing walls. The original drawings show that the first and second floors of the collapsed area were separated into two "houses" which were isolated from the rest of the structure and from each other by brick bearing walls. The third, fourth and fifth floors had corridors running through the bearing walls and thus were not isolated from the rest of the structure.

During the site investigation, a system of wrought-iron beams were found which had existed at the second floor level and had been supported by a cast-iron column between first and second floors. Research did not reveal when these beams were installed, but the beam measurements indicate that the beams were rolled between 1881 and 1891. Therefore, we conclude that this particular alteration took place between the years 1881 and 1911. This alteration removed the central bearing wall between first and second floors and supported the structure above on two pairs of wrought-iron beams which were supported at the center of the room by a cast-iron column resting on the central bearing wall. This alteration created a room of nearly 1,800 square feet area with only a single column near the center of the room. This room was adjacent to the Grand Ballroom and could have been used for functions in connection with that room.



The architect, J. Foster Ober worked on additions and alterations to the Hotel Vendome from 1882 until his death in 1896. No drawings have been found to indicate whether or not he was involved in the alterations at the second floor level.

In 1882 electric lighting was installed in several offices in the hotel; this was the first installation of electric lighting in a commercial building in the city of Boston.

In the years between 1911 and 1968 there were numerous minor alterations to the Vendome such as:

- Fire Escapes added
- Smoke Partitions added at certain stairs
- Sprinkler Improvements
- Elevator Improvements
- Removal of non-bearing partitions
- Install new ceiling in some areas
- Install ventilating system in one suite.

In 1968 an application was made to erect a 23-story hotel and apartment tower on the site of the Vendome. This application was denied for zoning reasons.

On June 30, 1971 an application was submitted to the Building Commissioner to make alterations to the building as follows:

“Renovate and recombine hotel rooms on floors two to seven to create 124 residential apartment units. Renovate street floor and basement to create shopping mall.” The Owner was listed as Pasquale Franchi of 425 Watertown Street, Newton, Massachusetts.

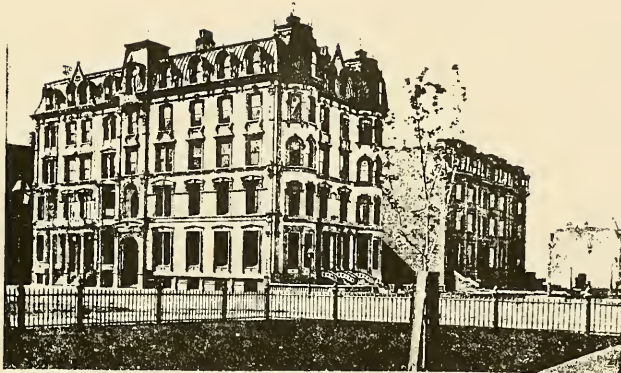
This application was denied on the basis of zoning regulations. An appeal was successfully made and a permit was granted to proceed on December 6, 1971.

Renovation work was still in progress at the time of the fire, in and adjacent to the collapsed area.

There were two other fires of record at the Hotel Vendome; one in 1956 and one in 1969. Neither of these occurred in the collapsed area.



NO. 40
HOTEL VENDOME—
CIRCA 1875 AND CIRCA 1911



From a photograph

Kindness of the Boston Real Estate Exchange

COMMONWEALTH AVENUE AT THE CORNER OF DARTMOUTH STREET
Showing the Hotel Vendome before the addition was built.

Circa 1875



THE VENDOME, BOSTON
Frank H. Abbott & Son

Circa 1911



III. SIGNIFICANT BUILDING ALTERATIONS

1. Alteration Circa 1890

This alteration completely changed the structural characteristics of this area of the building. The alteration involved removal of the central bearing wall between first and second floors and supporting the load above on a system of wrought-iron beams under the second floor. A cast-iron column was installed to support the ends of the beams at the center of the area. This column extended from the second floor to the first and rested on the central bearing wall which remained between the first floor and the basement floor.

Loading on the pile foundation from the central bearing wall which was formerly spread uniformly was now concentrated at one central point with areas to each side being relieved of load. A change such as this would encourage differential settlements which would place strains on the wall between basement and first floor.

The removal of the wall between first and second floors would have required "needling" for temporary support of the wall above. An operation such as this has the possibility of introducing strains and cracking which could weaken the masonry wall above.

The new support system which was introduced under the second floor was not well tied together. There were no bolted connections between the column cap plate and the double-I-beams. There were no anchor bolts tying the column base plate to the central brick wall and no lugs or recess on the base plate to hold the column in position. A 10-inch-I-beam running North and South which could have provided some lateral support merely rested on the double beams.

The double beams were not bolted to supports at East and West ends and were not well tied together where they butted one another over the cast-iron column.

2. Changes to Roof

The original roof consisted of a 7/8" thick wood deck on wood joists at 16" centers. Roofing felts were applied directly to this deck.

At some unknown date, the felts were removed and pitched concrete fill added which sloped from a maximum thickness of 7 inches to 2 inches at the drains.

Roof felts were applied to this pitched surface.



Over this was found a layer of quarry tile bedded in mortar and over the quarry tile was a layer of fiber board insulation topped with another layer of roofing felts.

In order to support the added weight, additional joists were interposed between each of the original joists. The extra joists were supported at header members by pressed steel beam hangers of a more modern design than the original wrought iron found throughout the building.

Our calculations indicate that this alteration added at least 75 pounds per square foot to the roof dead load or approximately 30,000 pounds additional dead load upon the cast-iron column between first and second floors.

3. Renovations of 1971 – 1972

The renovations of 1971-1972 were extensive, the intention being to convert floors two to seven into 124 residential apartment units and floors 1 and basement into a shopping mall. The work included:

- a. Demolition of certain partitions
- b. Repair weaknesses found in floor systems
- c. Construct new partitions
- d. Application of underlayment and finish to floors
- e. Installation of new hung ceilings
- f. Install new wall surfaces (taped gypsum board)
- g. Install new stair towers and elevator
- h. Mechanical, including plumbing, HVAC and sprinkler
- i. Electrical, including new distribution systems.

Architect for the renovation work was Stahl Associates of 177 Milk Street, Boston, Massachusetts.

Le Messurier Associates were Structural Consultants to the Architect.
Original Mechanical Design was by Vincent J. Piconi (Mass. P.E. Lic. No. 21311).
Revised Mechanical Design was by Irving I. Peltzman (Mass. P.E. Lic. No. 12936).
Original Electrical Design was by Vincent J. Piconi (Mass. P.E. Lic. No. 21311).
Revised Electrical Design was by Allen Robert Morris (Mass. P.E. Lic. No. 13505).

The above work was approximately 75% complete at the time of the fire.



At the time of the fire a large section of the first floor in the collapsed area had been removed and other areas supported on shoring while two parallel walls, one north and one south of the central bearing wall, were being removed. These walls had supported first floor joists and were to be replaced by steel beams resting on new brick piers.

During removal of debris, a vent duct 12" x 30" was found running north and south through the center of the collapse area under the first floor. The duct had been installed when Licensed Builder Joseph Lazo reported to the project on February 1, 1972.

The duct began at a louver opening over a window in the South wall and passed through the North wall beneath a central corridor. Measurements and calculations indicate that a portion of this duct passed beneath the bearing area of the cast-iron column between first and second floors.

4. Alteration to Chimney at South Wall

The original drawings by Architect W. G. Preston show three chimneys at the South wall. Photographs taken during the fire and before the collapse show three chimneys above the roof, but show three windows in the wall directly below the middle chimney. A portion of the South wall adjacent to these windows remained standing after the collapse exposing the interior surface of a blackened flue, indicating that the chimney had been used for some years prior to installation of the windows. Addition of window openings would weaken this wall to a degree making it easier to buckle under lateral pressures from the collapsed floor systems.

IV. SUMMARY OF FIRE

The fire started on Saturday, June 17, 1972 with the first alarm called in at 2:34 P.M.

According to the Fire Department, the fire started on the fourth floor in a bathroom under construction, immediately to the west of the collapse area.

An initial advance of the fire into the collapse area was checked by firemen. However, the fire made rapid progress upward, burned out the high penthouse tower, worked around to the Northeast corner of the solarium area and into the roof of the collapse area.

Additional alarms were sounded throughout the afternoon.

By 4:45 P.M., the fire was burning furiously under the roof of the collapse area; photographs indicate that portions of the roof had either collapsed or burned completely, prior to the general collapse.

At 5:28 P.M., while firemen were controlling fires in the exterior mansard and cornice, the entire 1,800 square foot area at the Southeast corner of the building collapsed, carrying nine firemen to their deaths and injuring eight others; some of whom were remarkably retrieved from the wreckage during the rescue operations which followed.



NO. 39

SOUTHEAST CORNER BEFORE COLLAPSE-
NOTE INTENSE FIRE IN ROOF STRUCTURE.
PHOTOGRAPH TAKEN BY JAMES B. FORGIE





COMMONWEALTH AVE.



DARTMOUTH ST.

HOTEL VENDOME

*Interior Renovation
Work in Progress Over
Entire Building at
Time of Fire & Collapse*

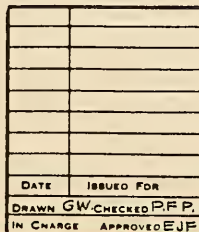
*Collapsed
Area*

*Original
Dartmouth St.
Building*

GENERAL KEY PLAN



		CITY OF BOSTON BOSTON, MASS.	
		INVESTIGATION OF COLLAPSE AT HOTEL VENDOME	
DATE _____ ISSUED FOR _____ DRAWN BY _____ CHECKED BY _____ IN CHARGE _____ APPROVED BY _____		MAIN CHAS T MAIN, INC. BOSTON, MASS. CHARLOTTE, N.C.	SCALE 1" = 10' - 0" JOB NO. 2944-1-R1 DWS NO.



SCALE
CLIENT JOB DWG NO
2944-1-R2

V. OBSERVATIONS AT COLLAPSE AREA BEFORE AND DURING REMOVAL OF DEBRIS

The collapse area measured approximately 45 feet (North and South) by 40 feet (East and West). The exterior wall at the South was completely collapsed; it was this wall which buried Ladder 15. Nothing could be seen of a center bearing wall formerly running across the area in an east-west direction. The East side or Dartmouth Street wall was partially collapsed; the Northerly half remained standing, but had no lateral support and was taken down after the site investigation was completed. At the West side of the collapse area, a high bearing wall remained standing, but in a precarious condition requiring immediate shoring if it was to be saved.

The floors were all collapsed and pitched downward from the sides of the area toward the center. The floor systems appeared to be relatively intact at the Northerly half of the area. Some of the floor systems at the Southerly half were flattened under the great load of bricks from the upper half of the South exterior wall. However, each joist was in its proper position and most joists had suffered only a small amount of damage.

The floor systems were packed one against the other with wall and ceiling material sandwiched between.

The roof was heavily burned and could no longer be identified as a unified system. A concrete roof fill varying in thickness from 2 to 7 inches was found in fragmented conditions with few pieces larger than two square feet in area. Fragments of this roof fill were found in the debris all the way to the basement floor.

The remaining fragments indicated that the roof had a 7/8" thick wood deck supported by 2" x 11" wood joists. Main supporting members running each side of the chimneys were 4" x 11". Indication was that roofing had at one time been applied directly to the wood deck, but a subsequent alteration added a pitched concrete fill with roofing on top. A portion of the area also had additional concrete fill with quarry tile embedded in top surface to create a sun deck area. There was evidence that this was unsatisfactory as a roof since a layer of fiber insulation board was found adhered to the quarry tile surface with additional roofing felts on top.

A few support girders were found with metal strap supports for joists between each of the typical mortised recesses. This indicated that additional roof joists were installed between the original joists, apparently to carry the extra weight of the concrete fill.



Examination of the floors showed a layer of plaster varying from one-half inch to one inch in thickness between the sub-floor boards and the finish floor boards. This may have been a levelling course, a sound barrier or a fire barrier. The floor joists were 2" x 12" wood (spruce or hemlock) with heavier 5" x 12" members running each side of each chimney. At the fireplace hearths, a 5" x 12" header supported four joists and was framed into the 5" x 12" supporting beams with an extremely well made mortise and tenon joint with wood peg locking it in place.

The floors were stiffened at the one-third points with 2" x 4" X-bridging. Wood laths were nailed directly to the bottom of the joists and a plaster ceiling applied. The alternations in progress at the time of the fire had applied a 5/8" "homasote" pressed paper board to the floor surface preparatory to placing finish tile or carpeting. A new hung ceiling of 1/2" gypsum board was being installed a few feet below the existing wood lath and plaster. The space between was being used for new piping, wiring and duct work.

Former piping, gas, steam, air tubes, speaking tubes and electrical wiring was left in place between existing joists.

The major floor members at each floor level (5" x 12") rested on the brick walls and were anchored to the walls by iron anchors driven into the top of the beam and tied back into the masonry.

The other floor joists (2" x 12") were not tied into the masonry, but merely rested in a pocket in the brickwork with 1-1/2" bearing depth. The joists were "fire cut" to allow easy release from the walls.

The first floor construction was different from the other floors. Joists varied from 3" x 9" to 3" x 10". A 1" x 2" strip of wood was nailed to each side of the joists and short 7/8" thick boards were cut to fit between joists and nailed to the 1" strip such that the top of joists and the floor boards were flush. It appeared that this construction was to support a terrazzo or mosaic floor as in the Grand Ballroom although none of this type floor could be found in the debris.

From the Grand Ballroom area in the remaining part of the building, a pair of 15-inch-I-beams could be seen protruding from the debris. It was apparent that these had been supported at the second floor level by a double beam lintel in the West wall. This lintel beam showed severe distortion of the flange where the two 15"-I-beams had slid off.



Approximately eight feet to the south of the pair of 15"-I-beams, a 12-inch-I beam was protruding from the debris. The end of the beam showed a flange fracture of a nature indicating that these beams might be of wrought iron.

When the North section of the fifth floor was almost completely exposed, during removal of the debris, a portion of the central bearing wall was found laying against it. The bricks and mortar in this portion were intact and there were vertical furring strips on each side. Charred surfaces on each side indicated that this portion originally was located between fifth floor and roof.

When the central bearing wall between the basement and first floor was uncovered, it was found to be in poor structural condition; difficulty was experienced in getting it to stay in position long enough to take measurements. As an area of wall became exposed, the outer wythe would fall away from the remainder and collapse. The mortar was very moist, with little or no adhesion to the bricks, and could be easily crumbled in the hand.

Following removal of all floors and nearly all of the debris a ventilation duct 12" x 30" was exposed in the Basement. All sections of the duct were found and measured. The duct was made of straight sections except for an offset at the south wall to meet a wall louver. Measurement of strap hangers found on the duct and measurements at the north wall showed that the duct had been approximately eight inches below the floor joists.





NO. 1
GENERAL VIEW
UPPER SECTION OF COLLAPSE AREA

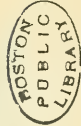


NO. 2
VIEW OF REMAINING WEST WALL



NO. 3

VIEW OF REMAINING NORTH WALL



NO. 4

VIEW OF REMAINING EAST WALL

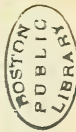




NO. 25

CAST IRON COLUMN
RESTING ON CRUSHED VENT DUCT
IN DOOR OPENING—

NOTE GRANITE BLOCK BEYOND—
NOTE CONDITION OF CENTRAL BEARING WALL.





NO. 35
VIEW LOOKING SOUTH
AT COMPLETION OF SITE INVESTIGATION-
NEAR AND FAR ENDS OF
BASEMENT VENT DUCT SHOWN.



VI. DETERMINATION OF FRAMING

To the best of our ability we have attempted to determine the structural framing systems as they existed immediately prior to the building collapse.

We have made this determination from a review of the original framing plans, review of the drawings for the 1971-1972 renovations, examination and measurement of debris and discussion with various organizations and individuals.

As found, the wood framing of floors and roof was substantially in agreement with the original framing plans by Architect W. G. Preston.

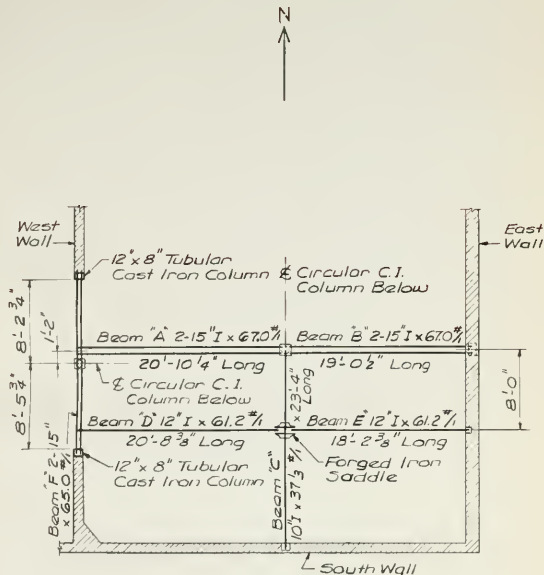
Drawing R4 shows typical floor framing encountered; roof framing was similar except smaller joists were used.

Estimated dead loads are also shown on Drawing R4.

The special support framing under the second floor was carefully measured as found and then re-assembled in the Parking Lot.

Drawing R3 shows a plan view of this framing as reconstructed with data shown for the various beams.





PLAN
RECONSTRUCTION OF 2ND FLOOR
SUPPORT FRAMING

BEAM DATA

Mark	Field Measurements				Shop Measurements			Rolled By	Date
	Depth	Flange	Web	Length	Depth	Flange	Web Wt./Ft.		
A	14 15/16	5 3/8	7/8	20'-10 1/4"	15.00	5.50	.813	Pennycoyd Iron Works	1887-1891
B	14 15/16	5 3/8	7/8	19'-0 1/2"	15.00	5.50	.813	do	do
C	10	4 5/8	1/2	23'-4"	10.00	4.625	.500	do	1887
D	11 11/16	5 7/16	3/4	20'-8 3/8"	12.00	5.375	.688	Pottsville Iron & Steel Co.	1887
E	11 11/16	5 7/16	3/4	18'-2 3/8"	12.00	5.375	.688	do	do
F	14 15/16	5 5/16+	—	—	15.00	5.375	.770	Carnegie Brothers & Co. Ltd.	1881, 1884

Source, Iron and Steel Beams
1873 to 1952, American Institute
of Steel Construction

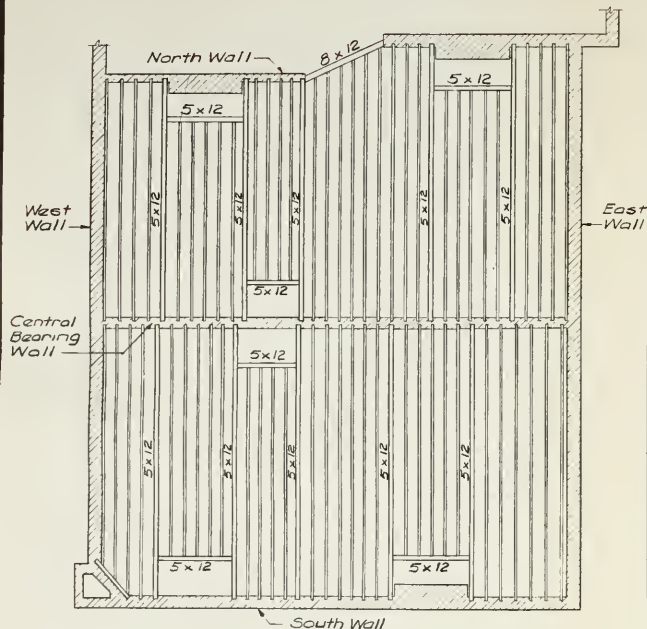
All Beams Are of Wrought Iron

NOTE:

Beams "A" and "B" Supported Central
Bearing Wall Which in Turn Supported
3RD, 4TH, and 5TH Floors and Roof.



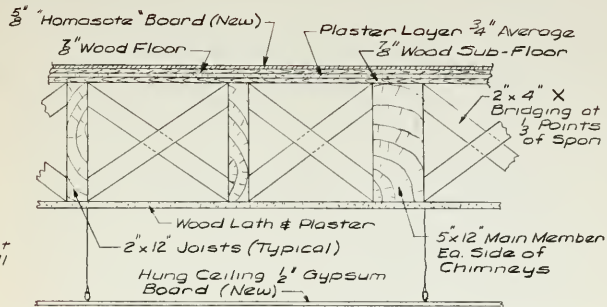
CITY OF BOSTON BOSTON, MASS.	
INVESTIGATION OF COLLAPSE AT HOTEL VENDOME	
DATE ISSUED FOR DRAWN G.W. CHECKER PFP IN CHARGE APPROVED J.F.	MAIN CHAS. T. MAIN, INC. BOSTON, MASS.
SCALE SHEET 200 ONE OF 20 2944-1-R3	



FRAMING PLAN - 5TH FLOOR

3RD & 4TH FLOORS SAME

All Floor Joists 2"x12" Except as Noted



TYPICAL FLOOR SECTION

FLOOR		ROOF	
ESTIMATE OF DEAD WEIGHTS		ESTIMATE OF DEAD WEIGHTS	
MATERIAL	WEIGHT PER SQUARE FT.	MATERIAL	WEIGHT PER SQUARE FT.
5/8" Homasote Board	2.0	Roofing Tar & Felts	4.0
3/8" Wood Floor	4.0	Quarry Tile	15.0
Plaster Fill	8.0	Concrete Fill	56.0
Wood Sub-Floor	3.0	Wood Deck	4.0
Wood Joists	5.0	Wood Joists	5.0
Misc. Piping & Wiring	2.0	Misc. Piping & Wiring	2.0
Existing Plaster Ceiling	8.0	Existing Plaster Ceiling	8.0
New Gypsum Ceiling	8.0	New Gypsum Ceiling	8.0
TOTAL	40.0 #/sq'	TOTAL	102.0 #/sq'

		CITY OF BOSTON BOSTON, MASS.	
		INVESTIGATION OF COLLAPSE AT HOTEL VENDOME	
		MAIN CHAS. T. MAIN, INC. BOSTON, MASS. QUANTICO, N. C.	
DATE	ISSUED FOR	SCALE	CLIENT JOB DWG NO.
DECEMBER 1940	G.W. CHECKED PEP		2944-1-R4
IN CHARGE	APPROVED EJT		





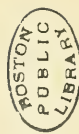
NO. 13

VIEW SHOWING
LAMINATED FLOOR CONSTRUCTION





NO. 14
VIEW OF 5TH FLOOR
INVERTED, RESTING IN PARKING LOT.



NO. 15
PART OF 3RD FLOOR
RESTING IN PARKING LOT.



NO. 24

GENERAL VIEW
OF 2ND FLOOR SUPPORT SYSTEM
AS FOUND IN DEBRIS-
ALL WROUGHT IRON BEAMS AND
THE CENTRAL CAST IRON COLUMN
CAN BE SEEN.





NO. 29

2ND FLOOR SUPPORT FRAMING
RE-ASSEMBLED IN PARKING LOT-
AS PHOTOGRAPHED FROM BUCKET ON CRANE.





NO. 30
FORGED IRON DOUBLE SADDLE-
THIS SUPPORTED ENDS OF
BEAMS 'D' AND 'E' FROM BEAM 'C'.





NO. 31

END OF 12 I BEAM ('D' OR 'E')—

NOTE FLANGE CUT TO FIT IRON SADDLE.





NO. 32

CONNECTION BETWEEN
DOUBLE I BEAMS 'A' AND 'B'
CAST IRON COLUMN
WAS DIRECTLY BELOW THIS POINT.



NO. 33

2ND FLOOR SUPPORT FRAMING RE-ASSEMBLED-
COLUMN BASE PLATE AND
STONE BEARING BLOCKS IN FOREGROUND.







NO. 34
END VIEW OF BASEPLATE AND
BEARING BLOCKS (RE-ASSEMBLED)



VII. DESCRIPTION OF COLLAPSE

The collapse was very rapid; only a few seconds of time could have elapsed from initial failure to completion. Once the initial failure took place, there was no way, given the nature of the structure as it existed, to prevent the complete collapse of the 1,800 square foot area. The roof structure had been extensively damaged by fire and had partially collapsed approximately 20 minutes before the collapse of the structure.

It is our opinion that the collapse was initiated by a bearing and/or shear failure of the bearing wall under a single central column between the second floor and the first floor (upper concourse level). The failure allowed this cast-iron column to drop to the basement level resulting in a complete collapse of the upper floors. (See R5 and R6.)

The cast-iron column had been supporting two sets of double 15-inch-wrought-iron-I-beams which, in turn, supported a 12-inch-brick-central-bearing wall extending all the way to the roof and supporting the second, third, fourth and fifth floors and the roof.

This wall had at least two doors or corridor openings through it at each level which minimized any possibility of arching action taking place.

When the column fell into the basement, the double-I-beams started downward at the center. At the East side, the double-I-beams were buried in the exterior Dartmouth Street wall. As the beams angled downward in the center, large rotational forces were set up in this anchorage which actually broke this section of wall causing the upper section to slide down. It was this material which buried the auto parked on the Dartmouth Street sidewalk.

At the West side, the double-I-beams were supported by another set of double beams running north and south. A large rotational force was also set up at this point; a flange of the supporting beam was bent and cracked and a section of brickwork was torn out of the West side bearing wall. The floors in the main part of the building tied into the opposite side of this wall and may have prevented a progression of the collapse in this direction.

With all support lost, the central bearing wall started to fall straight downward bringing the connected floor systems with it.



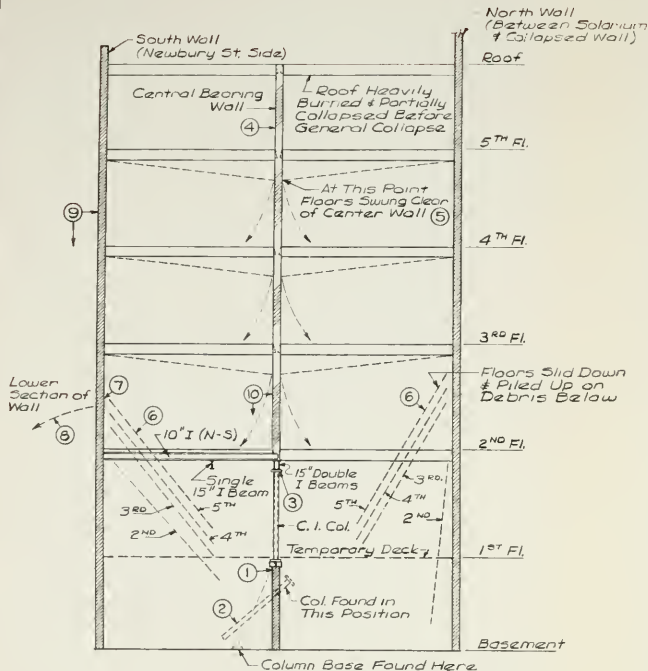


DIAGRAM OF COLLAPSE

Looking West

SEQUENCE OF COLLAPSE

- 1 Bearing Wall Fails Under Central Column
- 2 Column Falls into Basement
- 3 15" Double I Beams Drop in Center and Rotate Out of End Bearings.
- 4 Central Wall Starts Dropping.
- 5 When Central Wall Drops Two Feet, Floor Systems Slip Free.
- 6 Floor Systems Swing Against Walls, Break Free and Slide into Basement.
- 7 Floor Systems Lie Against Newbury Street Wall.
- 8 Lower Portion of Newbury Street Wall Gives Way Under Pressure From Floors. Rotates Outward, Burying Fire Engine.
- 9 Upper Part of Newbury Street Wall Collapses on Top of Debris.
- 10 Meanwhile, Central Wall Has Fallen into Basement Along With Fragments of Roof.



		CITY OF BOSTON BOSTON, MASS.	
		INVESTIGATION OF COLLAPSE AT HOTEL VENDOME	
		MAIN	
DATE ISSUED FOR		CHAS. T. MAIN, INC.	
DRAWN BY		DRAFTSMAN	
CHECKED BY		ENGINEER	
IN CHARGE		APPROVED BY	
		2944-1-R5	

[illegible]

NO. 36

COLLAPSE IN PROGRESS- CENTER SECTION
OF DARTMOUTH STREET WALL IS GONE-
FLOORS HAVE COLLAPSED-



SOUTH WALL IS DOWN BURYING ENGINE 15-
LADDER CAN BE SEEN AT LOWER LEFT
WITH LADDER OF ENGINE 17 ABOVE-
BAY WINDOW SECTION OF
DARTMOUTH STREET WALL
IS STILL STANDING.
PHOTOGRAPH TAKEN BY DONALD DIETZ



NO. 37

FINAL PHASE OF COLLAPSE

BAY WINDOW SECTION

CRUMBLING AND COLLAPSING

PHOTOGRAPH TAKEN BY DONALD DEITZ



NO. 38
SOUTHEAST CORNER BEFORE COLLAPSE-
NOTE WINDOWS IN SOUTH WALL
BELOW CHIMNEY-
COMPARE THIS PHOTO WITH NO. 36
PHOTOGRAPH TAKEN BY JAMES B. FORGIE



VIII. CONCLUSIONS

A. It is our opinion that prior to the fire on June 17, 1972, the stresses on the center bearing wall, under the cast-iron column, were excessively high and required only a small additional increase to cause failure.

We believe that the collapse of the structure was caused by a bearing and/or shear failure of the center masonry bearing wall under the cast-iron column at the first floor (upper concourse level), adjacent to the door and duct opening in the wall. (See R6.)

The collapse was probably due to a combination of the following factors:

1. The replacement of the bearing wall between the first and second floors around 1890 with wrought-iron beams and a cast-iron column resulted in excessively high bearing pressure on the masonry bearing wall below. The calculated dead load bearing values under the granite bearing blocks are well in excess of 500 psi, whereas accepted design values today on a wall in good condition with lime cement mortar would not exceed 150 psi. Tests on mortar indicate an ultimate compressive strength, when moist, of approximately 450 psi. The mortar in the existing wall was *not* in good condition. The masonry bearing walls are approximately 100 years old and the mortar exhibits very low strength characteristics, both in bond and bearing. It is our opinion that this alteration was the major factor contributing to the building collapse.

2. The addition, during the 1972 renovations, of a heating and ventilating duct opening (12" x 30") in the bearing wall in the highly stressed area under the column caused additional stress concentrations. We were unable to determine if a properly designed lintel was installed in this opening. Examination of the debris failed to uncover any such member.

3. The fire in this portion of the building which destroyed the roof, was responsible for the collapse, only to the extent that the large amount of water pumped into the building during the fire provided the additional load needed to trigger the collapse. This water probably contributed to further deterioration of the mortar as the mortar exhibits lower strength characteristics when wet. If the residual stresses in the building, however, had been within normal design limits, this water load should not have caused collapse of the structure.



B. Other information developed during our investigation included:

1. The stresses in the wrought-iron beams supporting the upper bearing walls were within normal design limits.

2. The cast-iron column at the first floor level which supported the upper floors of the structure had a safe design capability of supporting approximately 190,000 pounds with a factor of safety of about 3 (dead load plus live load). The computed dead load alone on the column was 190,000 pounds, prior to the fire.



REMOVAL OF DEBRIS

MAIN established a Field Office trailer and set it up in the parking lot at the corner of Dartmouth and Newbury Streets.

All interested parties were notified that site investigations would start on Monday, June 26, 1972.

On that day, representatives of many different organizations were on hand.

A meeting was held in the field office in an attempt to straighten out the chaotic situation and also to minimize the number of persons who would be operating in this hazardous area.

Personnel present and their representation were as follows:

Boston Fire Department:
Deputy Chief Magoon and Lieutenant Kelly.

Owner:
Franchi Development Trust
Pasquale Franchi and Counsel.

General Contractor and Construction Manager:
Eastern Builders, Inc.
Thomas Peters.

Architect:
Stahl Associates
Frederick Stahl and Roger Lang.

Structural Consultants to the Architects:
LeMessurier Associates
William LeMessurier, William Thoen, and Fred Cowen.

Investigating for the Boston Fire Department:
Walter J. Hickey Associates, Inc.
Roy O. Ventura.

Investigating for the Building Commissioner:
Chas. T. Main, Inc.
Paul F. Pierce.



Some ground rules were established and decisions reached as follows:

1. Everyone having business at the site will be logged in and out each day through MAIN's trailer.
2. Franchi will set up their own office in the West part of the building to control entrance of their personnel.
3. Boston Fire Department will require signed release from everyone entering building.
4. Efforts will be made to remove the fire engine first (Ladder 15).
5. Le Messurier Associates requested time to inspect the structure adjacent to the collapsed section.

June 27, 1972

Mr. Thomas Peters of Eastern Builders, Inc. advised against removing debris until adjacent structure was properly shored. Removal operations were rescheduled to commence on July 5, 1972.

July 5, 1972

Duane's crane set up in parking lot and took a strain on Ladder 15 aerial ladder to protect men working on and around engine. Crew of laborers picked off debris from above engine. At Noon, the area around base of aerial ladder was cleared. The mechanism was operated with a wrench and the ladder was swung 180° to point to Dartmouth Street.

An attempt was made to clean out behind Ladder 15 with the clam shell bucket, but this was soon stopped as the bucket was tearing into the collapsed floor systems.

July 6, 1972

Clifford Construction Company was engaged by the Fire Department. They started excavating behind Ladder 15 with a small clamshell bucket operated by a hydraulic crane. Laborers also continued to remove debris by hand.



The Fire Department wrecker moved in and put a tow line on the front of Ladder 15 while Duane's crane attempted to lift the cab section. This was unsuccessful as too much debris rested on the cab area.

The crane then lifted the tiller end and moved it southward about six feet. A lift was then made at the pivot point of the rig and it too was pulled southward.

The front end of Ladder 15 was then pulled sideways and freed without any of the debris shifting. At 4:45 P.M., Ladder 15 was towed away from the area.

On this day, two other agencies began investigation work at the site:

1. Edwards & Kelcey are representing CNA Insurance who holds coverage for Stahl, LeMessurier, Eastern Builders and also coverage on the building over and above that held by Liberty Mutual. Their work includes:

- a. Determination of cause of collapse.
- b. Determination of fire damage in remainder of building.
- c. Determination of suitability of building for reconstruction and usage.

2. Simpson, Gumpertz and Heger are representing Franchi Development Trust. They are making an independent investigation of the collapse.

After Ladder 15 had been pulled away from the debris, we were able to identify the floor systems in the position where they fell. Very little of the roof framing was left. Most that remained after the fire had been removed in the rescue operations.

The end of a 10" I beam was observed protruding from the second floor level between the floor joists.

July 7, 1972

Clifford Construction Company crew were released by the Fire Department. Duane was requested to bring in four laborers on Monday, July 10, 1972 to hand pick material from the top of the pile.



This day was spent taking observations, measurements and photographs. In the afternoon, two photographers and Duane's foreman went up in a flat pan bucket and carefully scanned and photographed the remaining walls and roof.

July 10, 1972

Laborers hand picking debris from top of pile, filling flat pan and dumping into container van supplied by Eastern Builders, Inc.

Duane took the laborers off of the pile shortly before Noon because of the loose bricks hanging above the Southwest corner of the area. Eastern Builders sent two men up in the flat pan. They scaled all loose material from the wall, but Duane did not wish to risk his men on the pile.

The open type clamshell bucket was then installed on the crane and worked quite well. A large amount of debris was removed without tearing into the floor systems.

July 11, 1972

The closed type clamshell bucket was installed and fragmented roof concrete and brick excavated from central area; we are attempting to expose more of the double I-beams. A section of brick wall was exposed laying against the Northerly part of the fifth floor and still intact although all loosened up. We determined that this was a section of the central bearing wall between fifth floor and roof.

Eastern Builders has agreed to make observations daily of the projecting wall at the Southwest corner of the area with a transit. We are also maintaining careful visual observations as well as photographing the wall daily.

The Northerly half of the fifth floor has been almost completely exposed.

At end of the day we had exposed a door opening in the central wall below the first floor; the wood jams and casings are in place, but the header is missing. There is a granite piece about 6" x 8" in cross section standing on end between the jams.



July 12, 1972

Eastern Builders brought in a large Payloader. Removed all debris on Dartmouth Street and extracted the auto which had been parked against the Dartmouth Street wall. Removal of the auto gave access to the basement windows from which the double I-beams could be seen angling sharply upward to the East wall.

The Payloader then moved into the Newbury Street parking lot and started loading the debris into 60 cubic yard capacity trucks furnished by Duane. A total of ten truck loads was removed this day. This material had been thoroughly combed, catalogued and photographed by all of the investigating agencies, as well as Fire Department personnel.

At 2:00 P.M. the East end of a single 12" I-beam was found bearing against the East wall and passing in a sweeping bend under the Southerly system of floors.

At 3:00 P.M. a large section of the fifth floor was lifted out and laid down in the parking lot in an inverted position. This section lifted cleanly away from the lath and plaster ceiling, leaving it resting intact against the fourth floor. The floor framing appeared to conform very well with the original plans. The major beams (5" x 12") showed minor checking, but the joists (2" x 12") showed no checking. The floor framing appeared quite sound; most damage occurred from the distortions caused from lifting it as a unit.

July 13, 1972

At 9:15 A.M. the Westerly section of the fourth floor (Northerly half) was lifted out. This section was partially burned and may have been adjacent to the starting point of the fire.

The Easterly half of the fourth floor was locked in tightly and could not be lifted as a unit; it was pulled apart by the bucked and taken out in small sections.

In the afternoon, excavation continued south of the central wall. A portion of the third interior bearing wall was exposed, also the single 12" I-beam. This beam was found to be in two separate parts which had rested on an iron strap saddle hung over the 10" I-beam previously discovered running north and south. The two ends of the beams were found quite widely separated; the East beam was pulled about 6 feet away from the saddle by the falling floor systems. The end of the West beam was found only a few inches from the saddle.

Ten truck loads of debris were removed from the site this day.



July 14, 1972

The North half of the third floor was lifted out in two sections and layed down in parking lot. This floor was not in as good condition as fourth and fifth, and showed evidence of recent extensive repairs. New 2" x 10" members had been spiked to sides of old joists. There were large cut-outs in old joists from past alterations.

The second floor was lifted out more or less in pieces being locked in by collapsed piping and impaled on protruding steel beams. This Northerly half of the second floor was found to have a structural weakness in that some of the floor joists were not long enough to reach to the central bearing wall. The licensed builder (Mr. Joseph Lazo) stated that this weakness had been discovered during the present alteration and that temporary supports had been placed while the structural engineers analyzed this condition.

Several large pipes (sprinkler main and water main) were encountered below the second floor. These pipes extended into the remaining structure. To facilitate removal of debris and prevent additional strain on the remaining structure, the pipes were burned off adjacent to the West wall. The Fire Department hosed down the area thoroughly before and after the cutting operation.

July 17, 1972

The remaining parts of the Northerly half of the first floor were lifted out. This floor was in poor condition; the flooring boards were weak from rot.

9:15 A.M. The top end of the Central cast-iron column was exposed. This column laid at an angle across the central bearing wall with the top end about 1'-0" north of the wall and the shaft passing through a door opening. The column rested directly upon a large sheet metal duct.

11:00 A.M. The entire column was exposed lying in a Southeasterly direction. Column was 7-3/4" outside diameter with 1-1/2" thick walls. There were no visible defects. The bottom end was square cut without any detail. The top end had a 14" x 14" x 2" plate cast with the column.

2:00 P.M. Removed 10" I and set it aside in lot.

Eleven (11) truck loads of debris removed from site this day.



July 18, 1972

Used flat pan bucket and laborers. Cleared an area north of center wall down to Basement brick floor. Fire Department ladders and the 75 foot aerial tower were used to measure beam bearing points. Measurements were taken across building between beam bearings. Original location of central column was determined by plumb bob suspended from the bucket on the aerial tower.

2:45 P.M. The column base plate (12" x 12" x 2") was found resting on the basement floor at a point 4'-6" due south of its original position. There was no debris under the plate; there were no lugs, socket, or bolts to hold the plate and column together.

All of the wrought-iron beams were re-assembled in the parking lot using the double saddle. The various components fitted together reasonably well and gave a very good picture of the structural system which had supported the entire collapsed area. The layout was photographed from the pan bucket suspended overhead by the crane.

In the late afternoon, level readings were taken of the important points in the collapse area and additional measurements taken of the building walls and other features.

July 19, 1972

Excavation was made to expose a vent duct which ran across the basement area to a louver which had been installed in the South wall. The duct sections were found and measured. Elevations were also determined.

The remaining areas of the first floor and temporary scaffolding and shores were removed. This brought removal operations to an end so far as our investigation was concerned.

Duane's crew and equipment was released and the area turned over to Eastern Builders, Inc. at the end of the day.

Six truck loads of debris were removed from the site this day.



Summary of Removal Operations

The cooperation between the various agencies making independent investigations was excellent. Especially appreciated was the assistance of the Boston Fire Department under the direction of Deputy Chief Leslie Magoon. Equipment and men were provided when needed to assist in the investigation.

The Duane Corporation crew worked smoothly with us at all times, operating only where requested and excavating with care, pausing while frequent observations and measurements were taken.

Representatives of the Owner and Builder cooperated fully and greatly expedited the removal of the debris. Prompt installation of shoring adjacent to the West and North walls adjacent to the collapsed area provided a greater measure of security to all personnel involved.



HERMAN G. PROTZE

MATERIALS TECHNOLOGIST 36 JACONNET STREET, NEWTON HIGHLANDS, MASS. 02161

(617) 332-8460

August 15, 1972

CHAS. T. MAIN, INC.
BOSTON, MASSACHUSETTS

TEST OF MASONRY MORTAR
HOTEL VENDOME INVESTIGATION
BOSTON, MASS., CTM JOB NO. 2944-1

REFERENCE NUMBER 72S-200

DATE RECEIVED 7-25-72

SPECIMENS One piece of hard burned, red-clay brick, 2 1/8 x 3 1/4 x 6" (broken end) and two pieces of mortar, approximately 1 x 3 x 7" as removed by you from subject project as described in your letter of transmittal dated July 25, 1972.

METHOD OF ANALYSIS Mortar samples each saw-cut to produce two companion prisms, dimensions as shown below. One mate specimen (each sample) soaked in water at 70°F for 64 hours then surface dried before test; other specimen (each sample) oven dried at 90°F, 50%R.H. for 64 hours before test. All specimens capped and tested in general conformity with ASTM C109.

Mortar Specimen	Dimensions			Density pcf	Compress Strength
	L	W	H		
1-Dry	1.27"	1.13"	1.44"	130	660psi
1-Wet	1.14	1.38	1.51	124	450
2-Dry	1.07	1.13	1.48	121	980
2-Wet	1.05	1.14	1.32	131	570

REMARKS The mortar appears to be a cement-lime mortar (not a pure lime mortar). Analysis for specific constitution (by any procedure) is not practical for this age mortar because it is not known whether the cement component comprises a Portland or a "natural" cement.

Respectfully submitted,

Herman G. Protze, Jr.
Herman G. Protze, Jr.





NO. 5
LOOKING EAST FROM GRAND BALLROOM
SHOWING EAST AND WEST BEARINGS
FOR DOUBLE I BEAMS—
END OF DOUBLE I BEAMS 'A'
VISIBLE IN DEBRIS BELOW







NO. 6
GENERAL VIEW
LOOKING DOWN AT DEBRIS
BEFORE START OF REMOVAL.





NO. 7
LOOKING EAST AT 5TH FLOOR
IN COLLAPSED POSITION

NO. 8

COLLAPSED LAYERS OF FLOORS AND CEILINGS
SEEN THROUGH DARTMOUTH STREET WINDOWS



NO. 9

COLLAPSED FLOOR SYSTEMS—
NORTH SIDE ROOF AT RIGHT,
5TH FLOOR IN CENTER,
4TH FLOOR AT LEFT





NO. 10

VIEW SHOWING

LAYERS OF ROOF CONSTRUCTION





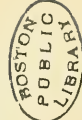
NO. 11

PORTION OF CENTER BEARING WALL
LAYING AGAINST 5TH FLOOR—
APPROXIMATELY FOUR STORIES
BELOW ORIGINAL POSITION.



NO. 12

VIEW OF FLOOR AND CEILING LAYERS
ON SOUTH SIDE
AFTER REMOVAL OF ENGINE 15.



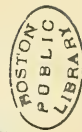


NO. 16
PART OF 2ND FLOOR
IN COLLAPSED POSITION
AND IMPALED ON STEEL BEAMS.



NO. 17

WEST SUPPORT FOR DOUBLE I BEAMS 'A'-
NOTE BENT FLANGE AND SECTION
TORN OUT OF WEST WALL





NO. 18

TOP FLANGE FRACTURES OF WEST WALL
BEAM 'F' AT SUPPORT POINT
OF DOUBLE I BEAM 'A'





NO. 19
WEST WALL SUPPORT POINT
FOR SINGLE I BEAM 'D'





NO. 20

EAST SUPPORT FOR DOUBLE I BEAM 'B'-
NOTE BRICKS TORN OUT BY BEAM ROTATION.



NO. 21
EAST WALL SUPPORT
FOR SINGLE I BEAM 'E'-
NOTE SCRATCHES ON WALL SURFACE
FROM FLANGES OF FALLING BEAM.





NO. 22

EAST SIDE DOUBLE I BEAM 'B' AS FOUND





NO. 23

UPPER END OF CAST IRON COLUMN AS FOUND-
WEST SIDE DOUBLE I BEAM 'A' AT RIGHT-
NOTE GRANITE BEARING BLOCK
RESTING ON END IN DOOR OPENING.



NO. 26

CRUMPLED VENT DUCT IN DOOR OPENING--
ALL DEBRIS CLEARED AWAY NORTH OF WALL--
NOTE DENT IN DUCT WHERE COLUMN RESTED.

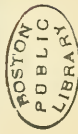
NO. 27
LOWER END OF CAST IRON COLUMN-
NOTE ABSENCE OF CONNECTING
LUGS, CLIPS ETC.





NO. 28

COLUMN BASE PLATE AS FOUND
RESTING ON BASEMENT FLOOR



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BY

CITY OF BOSTON, MASSACHUSETTS



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M3
Suppl.

W. M. HALL
G. R. RICH
W. J. LESSARD
C. A. DAUBER
WM. BAUMRUCKER

MAIN
CHAS. T. MAIN, INC.
Engineers

SOUTHEAST TOWER, PRUDENTIAL CENTER, BOSTON, MASSACHUSETTS 02199 • TELEPHONE 617-262-3200

September 11, 1972

2944-1

SUBJECT: Investigation of Collapse
at Hotel Vendome

Mr. R. R. Thuma, Jr.
Building Commissioner
City of Boston
City Hall
Boston, Massachusetts 02201

Dear Mr. Thuma:

Additional information, consisting of photographs of the center bearing wall in the area of the duct opening, have been made available to us through the courtesy of LeMessurier Associates. These photographs show very graphically the condition of the center-bearing wall prior to the collapse and should be compared with Drawing R6 following Page 13 of our report.

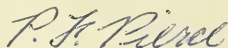
It is possible that the granite blocks which we have indicated as a bearing grillage, may actually have been part of a door lintel. If this were the case and the bearing plate under the column rested directly on the masonry, the calculated bearing pressures on the wall would have been approximately 1,400 psi, far beyond the compressive strength of the mortar.



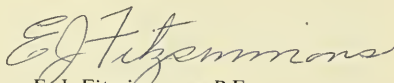
We think this additional information reinforces our original conclusions as to the cause of the collapse and suggest that this supplement be included as part of our report.

Very truly yours,

CHAS. T. MAIN, INC.



By: P. F. Pierce, P.E.

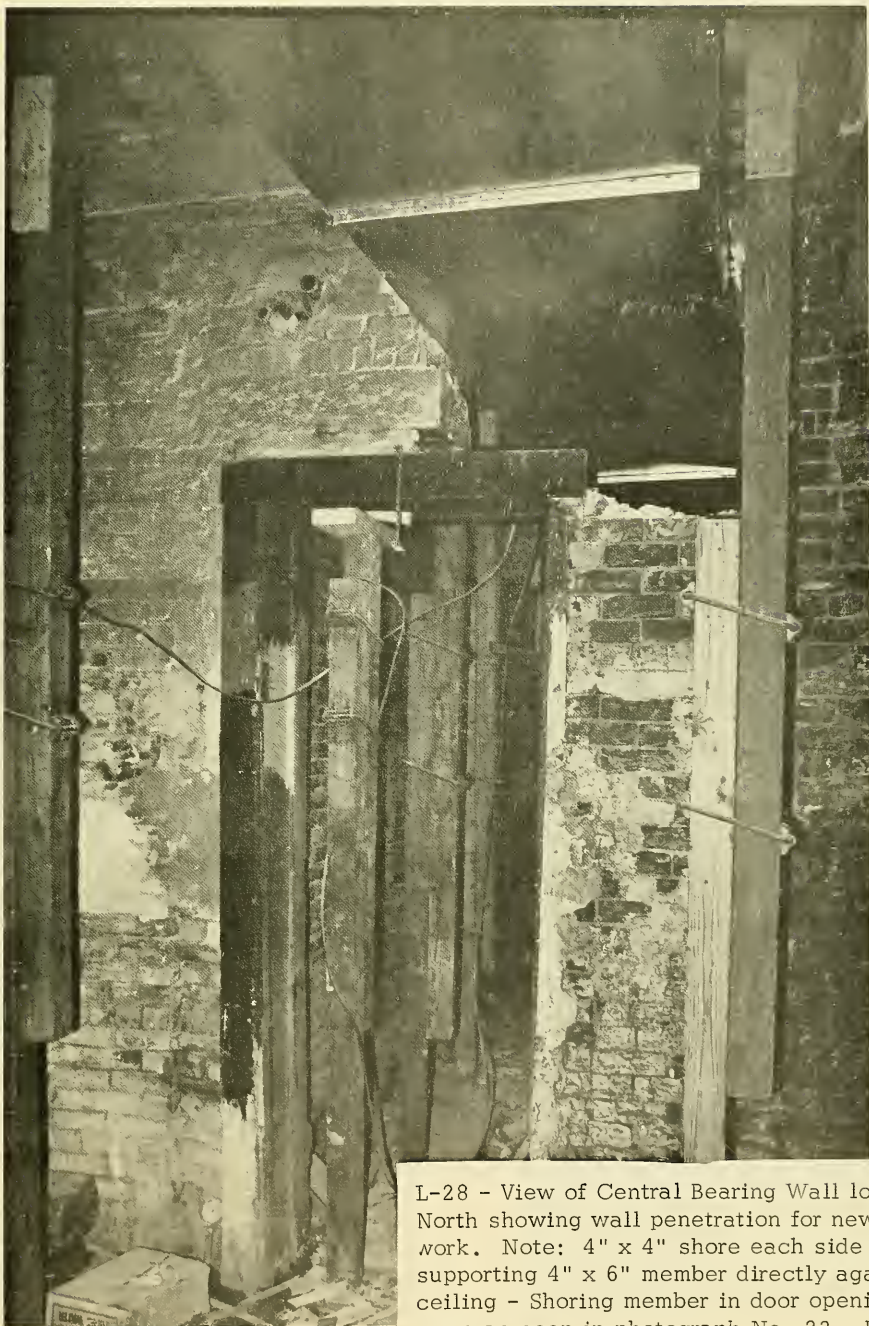


By: E. J. Fitzsimmons, P.E.

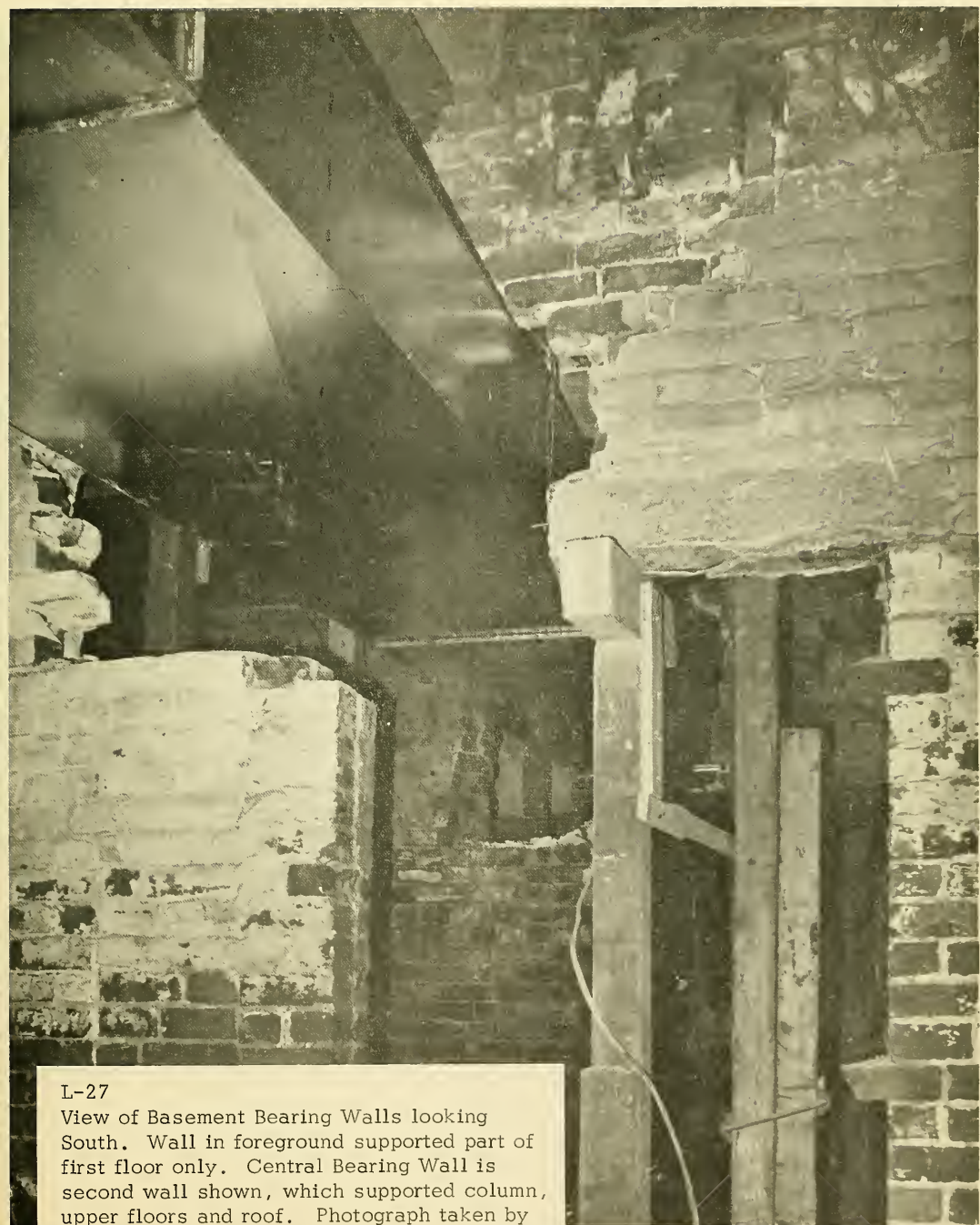
PFP/EJF/jh

Enclosures: Photographs L-27 and L-28





L-28 - View of Central Bearing Wall looking North showing wall penetration for new duct-work. Note: 4" x 4" shore each side of duct, supporting 4" x 6" member directly against ceiling - Shoring member in door opening is same as seen in photograph No. 23. Photograph taken by LeMessurier Associates in 1971.



L-27

View of Basement Bearing Walls looking South. Wall in foreground supported part of first floor only. Central Bearing Wall is second wall shown, which supported column, upper floors and roof. Photograph taken by LeMessurier Associates in 1971.



Boston Public Library

MAIN

CHAS. T. MAIN, INC.

Engineers

Southeast Tower, Prudential Center, Boston, Mass. 02199

1301 E. Morehead Street, Charlotte, N.C. 28204





